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TAL

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July 27, 1994

Dr. Mike Marcus
Federal Communications Commission
Field Operations Bureau
1919 M Street N. W.
Washington, DC 20554

Dear Mike,

I enjoyed our talk last week. I thought you might like to see the following items:

• A short report on some initial tests of the Metricom offering. I think that after you examine the data, that if Metricom doesn't get better round trip times through their network, they are in real trouble.

• A paper that Jim Lovette of Apple wrote on the ISM bands and Part 15.

• A corporate back grounder on my company for your information.

• A "ComputerLetter" excerpt.

I look forward to meeting with you soon on my next trip to Washington, DC.

Best Regards,

Dewayne

Dewayne Hendricks
President & CEO

Tetherless Access, Ltd. • 43730 Vista Del Mar • Fremont, CA 94539 • 510-659-0809

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Tetherless Access Ltd.

Company Profile

July 1994

Tetherless Access Ltd.
2468 Embarcadero Way
Palo Alto, CA 94303

TAL COMPANY PROFILE

TETHERLESS ACCESS LTD. (TAL) was formed in March of 1990 to develop products and services for the wireless data communications market. Located in California's Silicon Valley, TAL has formed key strategic alliances with other wireless technology companies in the area as a means of strengthening its marketing and technological base.

TAL was founded by Dewayne Hendricks (President/CEO) and Charles Brown (Chief Operating Officer). Both have extensive business start-up experience in the computer and electronics industry. In 1994, the company has been building its management team and business infrastructure in preparation for bringing products to market.

Privately held, TAL was self-financed from 1990-94, at which time it obtained an infusion of capital from a San Francisco-based investment firm in exchange for a minority equity share.

TAL's mission is:

> **To help extend the benefits of the Internet to new users worldwide by delivering economical solutions on multiple platforms for high-speed, wireless TCP/IP connectivity.**

At the core of the business is proprietary software technology by which a basic spread-spectrum packet radio—a "virtual wire" typically used for telco bypass with a range of up to 20 miles—is transformed into a TCP/IP-compliant packet radio routing device.

TAL has developed a strategic alliance with a Silicon Valley-based manufacturer of spread-spectrum radio equipment. The alliance partners have combined their respective technologies to develop prototypes and initial commercial models, and have established joint development plans and schedules for subsequent versions.

The radio is an FCC Part 15 compliant device operating within the 902-928 MHz band, one of three FCC-designated Industrial, Scientific and Medical bands (i.e., 902-928 MHz, 2.4 GHz, and 5.7 GHz). It uses a direct-sequence spread-spectrum modulation technique. The initial TAL device, called the SubSpace™ 2001, will offer customer throughput of up to 64 Kbps.

The SubSpace 2001 radio is approximately 9" wide by 9" deep by 3" high. It operates best on a line-of-sight basis and typically would be used with a roof-mounted omnidirectional or directional antenna.

TAL has deployed pilot networks in Telluride, CO, and San Diego, CA. The Telluride installation was as part of the community-based InfoZone project, which uses information and telecommunications technology to spur rural community development. The San Diego installation was a demonstration project that connected all of the libraries in greater San Diego, as well as the San Diego Zoo.

Currently, TAL is planning commercial trials in the San Francisco Bay Area of its products/services and a formal launch of the SubSpace 2001 in the latter part of 1994.

The TAL Network

The proposed TAL network consists of a collection of nodes owned by customers, TAL, and, potentially, other service providers, for exchanging data among geographically-separated computers. Data packets travel through this network from node to node according to addressing information contained in each packet's header and network connectivity information known to each node.

The TAL network will consist of the following:

- End nodes with TAL SubSpace units located on customers' premises and interconnected with the customers' host computers and LANs via industry-standard interfaces. Initially, these will be fixed-point sites, although TAL's intention is to accommodate mobile devices in the future.

- Base stations employing TAL technology and operated by TAL or another service provider (a TAL alliance partner). These will be established at appropriate locations within a metropolitan area to provide adequate geographic coverage to all customer sites.

- Interconnections among the base stations, either using wireline or wireless technology, that ultimately link to the Internet.

Within the TAL network, each node not only sends and receives its own traffic, but also relays the transmissions of nearby nodes. In other words, the TAL network operates as a mesh network, rather than in the star/hub configuration more commonly used for wireless networks. The efficiency of TAL's software allows relaying to take place while holding latency to acceptable levels within the network. This approach minimizes transmitter power and, consequently, the interference to nodes at other locations in the network that are trying to send traffic at the same time. It also reduces significantly the infrastructure investment required in a given geographical area, which brings significant cost savings to the end user. In addition, the TAL approach allows for considerable flexibility in network design.

As the node density in a given area increases, the average distance between nodes decreases. The SubSpace 2001 automatically adjusts its power output downward, thus decreasing potential interference. This effectively increases the carrying capacity of the network to help accommodate the additional users. In other words, the TAL approach is highly scalable .

The system is decentralized, making it more robust against the failure of critical nodes. Ideally, the system would operate with each node providing free relay services in exchange for being able to use the rest of the network to carry its own traffic. Such a model is not without precedent: the Internet itself operates under that model.

Target Markets

TAL's initial target markets include the following segments:

- Small- to medium-sized business seeking an Internet host connection with improved economics over telco leased-line alternatives.
- Businesses with multiple satellite sites in a metropolitan area looking for TCP/IP connectivity/Internet connectivity for the smaller sites.
- Large businesses reliant on TCP/IP networks in need of a backup to wireline systems as part of a disaster recovery plan.
- Businesses operating in areas where telecommunications infrastructure is poor or non-existent (i.e. developing nations or rural areas in the US) needing Internet connectivity.
- K-12 school systems, community colleges, and libraries looking for an economical way to interconnect their schools/branches and deliver the Internet to their students and the public.

TAL expects to take two prinicipal paths to market with its enabling technology. It intends to form strategic partnerships with first-tier Internet access providers, who wish to offer their customers new options for "last mile" connectivity, and to sell Internet access services directly to customers in selected geographical areas.

TAL anticipates an initial price of less than $4,000 for purchase of the SubSpace 2001. In addition, TAL customers will pay monthly fees for software maintenance and support and for full Internet connectivity.

Strategic Alliances

In addition to its manufacturing/product design strategic alliance, TAL has already formed several key strategic alliances with companies located in the Silicon Valley and other technology centers in the US:

- Apple Computer and TAL are mutually interested in the educational market for schools, libraries and non-industrialized international markets. Apple has supplied over $200,000 of computer equipment to date for TAL pilot networks in Telluride, CO, and San Diego, CA. TAL is also an Apple Partner within the Apple Developer Group.

- VITA (Volunteers in Technical Assistance), an Arlington, VA,-based non-profit dedicated to bringing technology expertise to developing nations, and TAL have developed a strategic alliance to deploy systems worldwide that marry VITA's little low-earth orbiting satellites and technology with TAL's technology and management expertise.

TAL has also begun investigating partners to assist in the economical deployment of TAL base stations. Existing providers of wireless services in the US, for example, who have already established infrastructure (e.g. towers and sites) to provide their cellular or SMR-based services could serve as allies in TAL's efforts.

The company has had numerous discussions with representatives in the US and from other countries regarding strategic alliances for marketing and distribution. This includes VADs and VARs, Internet access providers, and developers of communications-intensive application software.

The TAL Opportunity

Traffic on the Internet is estimated to be growing at as much as 10 to 20 percent *each month* . Businesses and other organizations worldwide are finding out how the use of the Internet puts them in better contact with their customers, their markets, and their strategic partners—in short, learning how to put the Internet to work for them.

TAL is poised to capitalize on these opportunities. By providing innovative options for connecting to the Internet and by delivering quality of service second to none, TAL will achieve its mission of bringing the benefits of the Internet to new users around the world.

From: cwi@netcom.com (Mike Cheponis)
Subject: thanks (fwd)
To: dewayne@netcom.com (Dewayne Hendricks)
Date: Sat, 9 Jul 1994 10:37:27 -0700 (PDT)
X-Mailer: ELM [version 2.4 PL23]
Mime-Version: 1.0

Forwarded message:
>From dave@hh.sbay.org Fri Jul 8 23:06:22 1994
Message-Id: <m0qMVTd-0000fBC@hip-hop.hh.sbay.org>
From: dave@hh.sbay.org (David Black)
Subject: thanks
To: cwi@netcom.com
Date: Fri, 8 Jul 1994 23:01:28 -0700 (PDT)
X-Mailer: ELM [version 2.4 PL23]
MIME-Version: 1.0
Content-Type: text/plain; charset=US-ASCII
Content-Transfer-Encoding: 7bit
Content-Length: 12700

Yeah, had some things to take care of Thursday night.

BTW, picked up a pair of the radios from Metricom today.
Using one right now - exploring their network.

You were at the experimenters' meeting with Bob Z., right?
Well they are renting/selling the modems. I can give you
a price list if you want.

I talked to a Roger Haas there about tech details;

Part 15 radios - 902-928. They use the
whole band by FH over 162 channels.

Radio is the size of a slim HT with 3.2" 1/4 wave
antenna attached. 1/3 of radio is NiMH battery.

Uses RS-232 serial connector, appears as Hayes
compatible modem to computer. DTE rate is autobaud
up to 38.4K, manually settable up to 115K. I
requested that in the next ROM release they
do up to 115K autobaud. They are in the process
of getting a new ROM done which will expand addressing
space and provide access controls not now in place.
(Right now, although we didn't pay for all services,
we can use any of them ;)). Also, they sell different
grades of service, from 2400 up to the max. bandwidth.
Roger said that even the 2400 user can get high bandwidth
but he has lower priority than "premium" service user
when passing data over the network.

On-air data rate is 77 Kbps. Roger said it was a compromise
between distance and speed. Higher speed = shorter distance.

The modems are full of goodies. I have been hacking
on one tonight. Following my note is output from
a hack session. Firmware goodies.

The modems I have (pal rented them) are at MCDN
(MicroCellular Data Network) addresses 01-09453
(mine) and other modem is 01-09397 (in Cupertino).

I am on the fringe coverage area, just north of Cupertino. I still can acquire a carrier from one poletop in Cupertino. The poletop units look like an upside-down box celular antenna (5/8 wave?)

Latency is pretty high, from 100ms up to seconds. Seems to vary a lot. Half-duplex of course. All things considered the modems work well. They automatically know whether to talk to another address through the network or direct, depending on whether they can hear the other modem.

If I want to connect to the Internet with PPP I type "atd intcup1**ppp" which means connect me to the Cupertino 1 Internet port with PPP. To access the PSTN (dialout from radio to data modems on PSTN) I use another form "atd 408354*7730768", i.e. to dial 408-773-0768. They do not allow LD calls to be made from the PSTN dialouts.

Radio seems to be solidly made, small (!) and charges battery while it operates. The battery is rated 6v 1100 mAH.

Here's a copy of the log after I discovered that typing something other than ppp after atd intcup1** gave me a menu and I started playing with it. The starmode and rlogin stuff has me stumped. I don't know how they work. The prompts are coming from within the modem - it goes out on the network to run the diagnostics.

All in all I am pretty impressed but wish for less latency and more consistent response. Both may be improved when I put the radio somewhere up higher. It's sitting in my windowsill at the moment and is holding a lock on the network with no problem, for hours now. It is not continuous transmit though.

Thought you might be interested. I have more info if you want... about their plans, etc. I think there's room for improvement but these people at Metricom have something good going here.

Dave

```
---
atz
OK
at&v
S00:001 S01:000 S02:02b S03:00d S04:00a S05:008 S06:000 S07:03c S08:001 S09:000
S10:000 S11:000 S12:000 S13:000 S14:000 S15:000 S16:000 S17:000 S18:000 S19:000
S20:000 S21:000 S22:000 S23:000 S24:000 S25:000 S26:000 S27:000 S28:000 S29:000
S30:000 S31:000 S32:000 S33:000 S34:000 S35:000 S36:000 S37:000 S38:000 S39:000
S40:000 S41:000 S42:000 S43:000 S44:000 S45:000 S46:000 S47:000 S48:000 S49:000
S50:000 S51:000 S52:000 S53:000 S54:000 S55:000 S56:000 S57:000 S58:000 S59:000
S60:000 S61:000 S62:000 S63:000

OK
atd intcup1**foo
SAP access numbers ("^C" to exit):
        201     remote login
        202     transparent ("+++" to exit)
```

```
        203     loopback
        204     ping
        205     starmode
        210     tracer

OK
atd intcup1**201
Rlogin> 01-09397
Rlogin>
Rlogin>  +++
OK
ath
OK
atd 01-09397**foo
SAP access numbers ("^C" to exit):
        201     remote login
        202     transparent ("+++" to exit)
        203     loopback
        204     ping
        205     starmode
        210     tracer

OK
atd 01-09397**204
Ping> j
Tries:   1 of 1
 Rcvd:   1 of 1 -- 3568mS

Pings from '01-09453' to '01-09397':
        Rate:0  Size:100  Number:1
        Tries:1  Out:1  In:1 => Min:3568  Max:3568  Avg:3568
        FirstTx: 3121178mS  LastRx: 3124746mS  Total Elapsed: 3568mS

Ping>  +++
OK
atd 01-09397**tracer
Tracer> foo
Tracer>
WAN: 00.00.00.00.00.00 d5 =>   4       668 mS
WAN: 4a.e5.dd.49.b8.60 11 =>   0        19 mS
WAN: 4a.e9.e5.49.a2.80 ca =>   0        41 mS
WAN: 00.00.00.00.00.00 ae =>   0        27 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>   0        42 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  14      3078 mS
WAN: 00.00.00.00.00.00 d5 =>          4112 total time in mS

Tracer> bar
Tracer>
WAN: 00.00.00.00.00.00 d5 =>   1       107 mS
WAN: 4a.e5.dd.49.b8.60 11 =>   0        18 mS
WAN: 4a.e9.e5.49.a2.80 ca =>   0        40 mS
WAN: 00.00.00.00.00.00 ae =>   0        27 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>   0        42 mS
WAN: 4a.e5.dd.49.b8.60 11 =>   0        30 mS
WAN: 00.00.00.00.00.00 d5 =>           498 total time in mS

Tracer> bar
Tracer>
WAN: 00.00.00.00.00.00 d5 =>   0         4 mS
WAN: 4a.e5.dd.49.b8.60 11 =>   0        19 mS
WAN: 4a.e9.e5.49.a2.80 ca =>   0        40 mS
WAN: 00.00.00.00.00.00 ae =>   0        24 mS  <Destination>
```

```
WAN: 4a.e9.e5.49.a2.80 ca =>  0       43 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  9     2051 mS
WAN: 00.00.00.00.00.00 d5 =>        2437 total time in mS

Tracer> bar
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  9     2236 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0       19 mS
WAN: 4a.e9.e5.49.a2.80 ca =>  0       47 mS
WAN: 00.00.00.00.00.00 ae =>  0       24 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>  0       43 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  2      248 mS
WAN: 00.00.00.00.00.00 d5 =>        2883 total time in mS

Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0        3 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0       19 mS
WAN: 4a.e9.e5.49.a2.80 ca =>  0       40 mS
WAN: 00.00.00.00.00.00 ae =>  0       24 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>  0       42 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  5     1371 mS
WAN: 00.00.00.00.00.00 d5 =>        1744 total time in mS

Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  6     1499 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0       19 mS
WAN: 4a.e9.e5.49.a2.80 ca =>  0       40 mS
WAN: 00.00.00.00.00.00 ae =>  0       24 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>  0       42 mS
WAN: 4a.e5.dd.49.ab.c0 2b =>  1      116 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  9     1984 mS
WAN: 00.00.00.00.00.00 d5 =>        4098 total time in mS

Tracer> +++
OK

Tracer Summary

  Number returned 6 out of 6
  Minimum Time    498 mS    Minimum Hops   6
  Maximum Time   4112 mS    Maximum Hops   7
  Average Time   2629 mS    Average Hops   6
  Milliseconds per Hop (min / max / ave): 83 mS  685 mS  438 mS

OK
atd **205
*> foo
*> start
*> +++
OK
atd **tracer
Tracer> 01-09397
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0        4 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0      452 mS
WAN: 4a.e9.e5.49.a2.80 ca =>  0       48 mS
WAN: 00.00.00.00.00.00 ae =>  0       27 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>  0       43 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0      461 mS
WAN: 00.00.00.00.00.00 d5 =>        1269 total time in mS
```

```
Tracer> intcup1
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0         3 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0       457 mS
WAN: 4a.e9.e5.49.a2.80 ca =>  0        40 mS
WAN: 00.00.00.00.00.00 ae =>  0        24 mS  <Destination>
WAN: 4a.e9.e5.49.a2.80 ca =>  0        42 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0       271 mS
WAN: 00.00.00.00.00.00 d5 =>         1057 total time in mS

Tracer> +++
OK

Tracer Summary

  Number returned 2 out of 2
  Minimum Time   1057 mS    Minimum Hops   6
  Maximum Time   1269 mS    Maximum Hops   6
  Average Time   1163 mS    Average Hops   6
  Milliseconds per Hop (min / max / ave): 176 mS  212 mS  194 mS

OK
atd
ERROR
at**205
OK
atd **ping
Ping> 01-09397
Tries:   1 of 1
 Rcvd:   1 of 1 -- 4750mS

Pings from '01-09453' to '01-09397':
        Rate:0  Size:100  Number:1
        Tries:1  Out:1  In:1 => Min:4750  Max:4750  Avg:4750
        FirstTx: 3304946mS  LastRx: 3309696mS  Total Elapsed: 4750mS

Ping> intcup1
Tries:   1 of 1
 Rcvd:   1 of 1 -- 880mS

Pings from '01-09453' to '01-09397':
        Rate:0  Size:100  Number:1
        Tries:1  Out:1  In:1 => Min:880  Max:880  Avg:880
        FirstTx: 3316241mS  LastRx: 3317121mS  Total Elapsed: 880mS

Ping> +++
OK
atd 408354**tracer
Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0         7 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0        17 mS
WAN: 4a.f0.45.49.b8.60 0d =>  0        41 mS
WAN: 4a.f5.d5.49.de.c0 54 =>  0        26 mS
WAN: 4a.f9.dd.49.e7.a0 c9 =>  0        27 mS
WAN: 4a.fb.95.49.fd.20 83 =>  0        30 mS
WAN: 4b.04.2d.4a.24.c0 74 =>  0        32 mS
WAN: 4b.05.65.4a.27.9d eb =>  0        38 mS
WAN: 00.00.00.00.00.00 cd =>  0        34 mS  <Destination>
WAN: 4b.04.e5.4a.23.20 b5 =>  0        31 mS
WAN: 4b.04.2d.4a.24.c0 74 =>  0        34 mS
```

```
WAN: 4a.f2.65.49.9f.40 f4 =>  0          52 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  5        1271 mS
WAN: 00.00.00.00.00.00 d5 =>           2664 total time in mS

Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0           3 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0          17 mS
WAN: 4b.03.45.49.c5.40 40 =>  0          27 mS
WAN: 4b.00.a5.49.c8.20 ff =>  0          27 mS
WAN: 4a.fd.85.4a.32.e0 8b =>  0          28 mS
WAN: 4b.05.65.4a.27.9d e1 =>  0         303 mS
WAN: 4b.05.65.4a.27.80 c9 =>  0          29 mS
WAN: 00.00.00.00.00.00 cd =>  0          30 mS  <Destination>
WAN: 4b.05.65.4a.27.9d e1 =>  0          30 mS
WAN: 4a.f7.a5.4a.24.c0 95 =>  0          41 mS
WAN: 4a.f3.35.49.aa.a0 9b =>  0          35 mS
WAN: 4a.e7.95.49.c9.5e e9 =>  0          36 mS
WAN: 4a.e5.dd.49.b8.60 11 => 12        3126 mS
WAN: 00.00.00.00.00.00 d5 =>           4418 total time in mS

Tracer> +++
OK

Tracer Summary

  Number returned 2 out of 2
  Minimum Time   2664 mS    Minimum Hops  13
  Maximum Time   4418 mS    Maximum Hops  13
  Average Time   3541 mS    Average Hops  13
  Milliseconds per Hop (min / max / ave): 205 mS  340 mS  272 mS

OK
atd 408241**tracer
Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  6        1401 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0          21 mS
WAN: 4a.eb.85.49.f9.20 c7 =>  0          28 mS
WAN: 00.00.00.00.00.00 a3 =>  0          36 mS  <Destination>
WAN: 4a.eb.35.49.f8.a0 43 =>  0         369 mS
WAN: 4a.e6.25.49.dc.c0 29 =>  0         181 mS
WAN: 4a.e5.dd.49.b8.60 11 => 12        2983 mS
WAN: 00.00.00.00.00.00 d5 =>           5277 total time in mS

Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>  0           3 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  0          21 mS
WAN: 4a.eb.85.49.f9.20 c7 =>  0          28 mS
WAN: 00.00.00.00.00.00 a3 =>  0          29 mS  <Destination>
WAN: 4a.eb.35.49.f8.a0 43 =>  0          28 mS
WAN: 4a.e6.25.49.dc.c0 29 =>  0          27 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  7        1607 mS
WAN: 00.00.00.00.00.00 d5 =>           2017 total time in mS

Tracer> +++
OK

Tracer Summary

  Number returned 2 out of 2
```

```
  Minimum Time    2017 mS    Minimum Hops   7
  Maximum Time    5277 mS    Maximum Hops   7
  Average Time    3647 mS    Average Hops   7
  Milliseconds per Hop (min / max / ave): 288 mS  754 mS  521 mS

OK
atd 408654**tracer
Tracer> .
Tracer>
WAN: 00.00.00.00.00.00 d5 =>   6       1451 mS
WAN: 4a.e5.dd.49.b8.60 11 =>   0        243 mS
WAN: 4a.e6.25.49.dc.c0 29 =>   0        190 mS
WAN: 4a.d4.8d.4a.1c.a0 08 =>   0        507 mS
WAN: 00.00.00.00.00.00 26 =>   0         36 mS  <Destination>
WAN: 4a.d4.3d.4a.1c.a0 c6 =>   0        231 mS
WAN: 4a.e9.95.49.94.c0 25 =>   0         48 mS
WAN: 4a.e5.dd.49.b8.60 11 =>  24       6459 mS
WAN: 00.00.00.00.00.00 d5 =>           9713 total time in mS

Tracer> +++
OK

Tracer Summary

  Number returned 1 out of 1
  Minimum Time    9713 mS    Minimum Hops   8
  Maximum Time    9713 mS    Maximum Hops   8
  Average Time    9713 mS    Average Hops   8
  Milliseconds per Hop (min / max / ave): 1214 mS  1214 mS  1214 mS

OK
```

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DARWINISM AND THE ISM BANDS

JIM LOVETTE
APPLE COMPUTER, INC.

"I love fool's experiments. I am always making them."
Charles R. Darwin, Letters, 1887.

I. INTRODUCTION

Apple has previously described a frequency hopping technology that employs error-correcting measures to achieve robust data delivery in an inherently hostile spectrum environment. This paper will trace how the "ISM bands" have developed in the nearly nine years since they were made available for communications, and will suggest that the 2400 MHz band is following the development archetype of the 900 MHz band, offset by several years. If so, there are overwhelming reasons to believe that the 2400 MHz band will be a feral territory for operation of wireless LANs. The transmission methods most likely to survive are those that are adapted to this environment and able to deliver customers the quality of service required to create and expand a viable market, in the presence of the unpredictable interference from primary licensed users, from high-powered in-band devices and from other unlicensed applications.

We also will briefly discuss implications of last month's change, resulting from Congressional action, of the regulatory aegis for much of the 2400 MHz band.

II. THE ISM BANDS

The first thing we have to recognize is that the "ISM" bands were never intended for communications. They were, and still are, designated primarily for just what their oft-misused moniker suggests: industrial, scientific and medical uses of RF energy, to heat and light and cure, to identify and locate, and a myriad other tasks beneficial and even essential to our society. A close look at the rules for those primary usages of the band show that there are no limits on the radiated power that ISM devices can emit, within "their" bands. No limits at all.[1]

Here is the formal descriptor for ISM, as stated in ITU, Radio Regulations, Resolution 68, Geneva, 1982, and replicated currently in the Definitions in Part 2.1, FCC Rules (CFR 47):

> "Industrial, Scientific and Medical (ISM) (of radio frequency energy) Applications. Operation of equipment or appliances designed to generate and use locally radio-frequency energy for industrial, scientific, medical, domestic or similar purposes, *excluding applications in the field of telecommunications*."
>
> (emphasis added)

When the inventive Dr. Mike Marcus of the FCC set out in 1981 to find a home for newly rediscovered spread spectrum technology, many ideas were considered, including allowing the overlay of 70-Watt devices on TV broadcast spectrum. Ultimately, the FCC

[1] "ISM equipment operating on a frequency specified in §18.301 is permitted unlimited radiated energy in the band specified for that frequency." FCC §18.305 (a).

decided that, while the ISM bands were far from ideal, little harm would be done to the ISM emitters by giving spread spectrum purveyors opportunistic access to what they fondly call the "garbage bands."

Urged on by an eager communications industry, the FCC adopted Rules on May 9, 1985, permitting constrained implementations of spread spectrum in the ISM bands.

To the dismay of the FCC, that industry then took its time developing communications products. The first equipment authorization under the new rules wasn't granted until four years later, on August 10, 1988, to Telesystems SLW of Canada. Reflecting the snail's pace of the regulatory "un-due process," almost before products began to be developed, the FCC was asked[2] to revise their rules, in some cases to clarify them but also to allow much greater bandwidth for frequency hopping systems which had been limited to a bandwidth of only 25 kHz .

Even before there was any significant band development, confrontations surfaced between the upstart unlicensed Part 15 devices and emplaced users of the band,[3] a process that continues and is even heating up today. This provoked the FCC to articulate its philosophies about communications devices using the ISM bands:

> "As far as interference to the Part 15 device is concerned, this was not something we even really addressed when we opened up bands to Part 15 operation. There was concern over whether we should even (do so) because of the large and increasing number of high-power authorized services in (the bands).[4]

These philosophies still appear to prevail. One manufacturer asked what would happen when products receive interference. An FCC spokesperson replied:

> "I think that, sir, you have had prior notice that you are operating on a sufferance basis. . . . You made a marketplace decision. If you succeed, then you reap the benefits of the success. If you fail, then you've taken your chances and lost. Part 15 is still Part 15." [5]

III. DEVELOPMENT OF THE ISM BANDS.

Those who cannot remember the past are condemned to repeat it.
George Santayana 1906.

In July, 1990, (neatly coinciding with the transmutation of 802.4L to 802.11), the FCC released its revised, more useful spread spectrum rules, now permitting 0.5 and 1.0 MHz-wide frequency hoppers. Even at this outset, apprehensions about harmful interference to wireless LANs were keenly felt. The PAR for the IEEE Committee read:

> "The initial effort will be for the ISM bands and to consider the use of additional bands beyond ISM. However, these ISM bands are already heavily used,

[2] By Apple, California Microwave and others.

[3] e.g., Sensormatic Corporation, maker of anti-shoplifting devices.

[4] John Reed, FCC Engineer, during FCC presentation at a TIA-sponsored Part 15 seminary in July, 1989.

[5] Frank Rose, of the FCC, at same event. Both as quoted in Federal Communications Technology News ("FCTN").

and it is felt that service degradation from other users will happen, increasing with time."

Other parties expressed similar concerns. NCR, for example, advised the FCC that while the ISM bands "currently provide acceptable service to users of wireless LANs, . . . [t]he ISM bands will necessarily become less and less serviceable for large scale ubiquitously available radio services over time."[6]

IBM stated to the Commission that "[t]he experiences with shared ISM frequencies . . . make clear that the acceptance of wireless LAN technology depends upon an assurance against interference."[7]

Apple dwelt at length on the subject in its "Data-PCS" petition, saying that:

"Apple has concluded that . . . operation in the ISM bands ultimately will be unworkable, because there is a strong likelihood of unpredictable, and essentially uncontrollable, interference in the ISM bands. . . . Accordingly, given present and anticipated operating conditions in the ISM bands, it would be reckless for the computer industry to ignore these trends and expect ISM frequencies to be a realistic medium for Data-PCS operation through the decade."

IEEE 802 told the Commission that:

"IEEE 802 now has work underway to prepare a LAN standard for data communication over a radio medium. This work is currently exploring the frequency bands for ISM using the Commission's spread spectrum rules. Data communication in the ISM bands is unprotected from higher power transmitters. . . . In addition, many other services are evolving under Section 15.247 and the ISM bands will over time have limited usefulness for data communication."[8]

In spite of continuing industry-wide worries about interference, the growth in the rate of equipment authorizations over the last four years has been remarkably smooth, marred only by a slight decline in 1993. The 22 certifications issued for 900 MHz equipment,[9] and the six issued for 2400 MHz apparatus,[10] in the first seven weeks of 1994, blizzard shutdowns at the FCC labs notwithstanding, suggest that the pace may even be accelerating. (See Fig. 1, next page).

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6 NCR Comments on RM 7618, April 10, 1991.

7 IBM Comments on RM 7618, April 10, 1991

8 Response of the IEEE 802 Local Area Network Standards Committee to the FCC's PCS NOI., Gen Docket 90-314.

9 These include some cordless phones, wireless mikes, a "personal detection unit" and other devices not in 802.11's interest areas.

10 Which include products from WINData, Proxim, Symbol Technologies, and two field disturbance sensors.

Figure 1

Most users of the ISM bands, however, including most 802.11 participants, would probably offer no first-hand anecdotal evidence of harmful interference in the 2400 MHz band from unknown sources (or even from known sources other than microwave ovens). Why, then, does Apple advocate a frequency-hopping protocol that is specifically adapted to survive interferers?

IV. Specific ISM Bands

A) 900 MHz. Is it a useful prototype?

In spite of concerns about interference, manufacturers started introducing Part 15 products for communications in the 900 MHz band because there was, in effect, no alternative. In 1990, some 14 consumer/residential video distribution devices alone were certified. More recently, 900 MHz cordless telephones are proliferating, along with a variety of wireless data devices. RF-actuated identification transponders, and their sometimes-powerful base stations, are also becoming ubiquitous, in stores and offices and even along highways.

What is shown in Figure 1, above, is only part of the story; it does not include, among other things, licensed applications and their related devices (or, of course, microwave ovens).

A case in point:

Last year, the FCC proposed to allow automatic vehicle monitoring (AVM) systems, that have been developing in the 900 MHz band under interim Rules, to emerge full-blown as a permanent, primary user of all the 902-928 band, deploying virtually ubiquitous base station transmitters of 300 watts ERP.[11] Teletrac, for example, has amassed licenses for constructing at least 986 transmitters in the band, with six or more high power base transmitters in many cities to assure coverage. Ameritech has obtained hundreds of similar licenses. As of last June, Teletrac systems in only six cities had been "turned on," but Teletrac had already attempted to shut down Part 15 devices because of claimed interference.[12]

Sparked by threats that AVM could render the band unusable by other applications, unlicensed 900 MHz equipment makers formed the Part 15 Coalition to represent their interests.[13]

In pleadings before the FCC on AVM, many companies have described their use of the 900 MHz band in terms that, when taken together, foreshadow an awesome number of devices and systems "in the works" for deployment in the 902-928 MHz band. Some highlights:

Itron noted that more than 3 million of its utility meter-reading low-power 900 MHz transmitters have been installed.
Clinicom represented that it had an installed base of more than 3000 terminals used by medical professionals on 900 MHz.
American Association of Railroads asserted that it is deploying ID tags on 1.4 million railroad cars by the end of 1995, watched by 3000-5000 tag readers (transmitters).
American President Companies said that 4.5 million shipping containers are being tagged.
AMTECH advised they are equipping "nearly 100,000 new vehicles a month." AMTECH's transmitters use 32 watts ERP, but they point out that some systems will require transmitters operating at 5 KW ERP and mobiles at 50 Watts each.
ADEMCO, the worlds largest maker of security equipment, pointed out that "a host of new . . . consumer devices will be introduced to the marketplace within the next few months. . . . The introduction of these new devices is sure to create an untenable interference situation."
Norand, which holds equipment authorizations for five 900 MHz devices, claims more than 2000 installations for industrial data collection.

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[11] See FCC NPRM on RM-8013, released April 9, 1993. To get ahead of the sequence of this paper, the FCC also calls attention to the availability of 2450-2483.5 MHz for Private Land Mobile stations. See FCC §90.75.

[12] This paper will not address the right of a licensed service to force unlicensed operations to be stopped in cases of interference.

[13] Recently, the Coalition counted more than 40 members, including numerous 802.11 participants. The organization states that its members have invested "nearly 2 billion dollars" to date on 900 MHz equipment. Contact information: Steve Shear, (408) 735-6690.

The **Alarm Industry Communications Committee** indicated that more than 200,000 alarm systems using Part 15 radio links are currently in operation.

Sensormatic tabulated sales of more than 100,000 anti-shoplifting systems (along with "billions" of tags and labels).

Recoton said they have sold more than 300,000 consumer devices for the 900 MHz Part 15 band, used primarily for wireless stereo headsets and speakers.

Compared with the applications mentioned above, ham operations have historically not caused difficulties for unlicensed services operating on a secondary basis. However, the growth of 900 MHz ham activities is of interest, since ham operators can use relatively high power levels. Each repeater tabulated in Figure 2 represents a community of individual operators.[14]

Figure 2

This recitation could continue on and on, with similar activities, most of which are only now making it to the market.[15] Three years ago, it was difficult to find a signal on 900 MHz; today in some shopping areas and industrial parks, it is almost impossible to find a quiet zone. Both narrowband and wideband signals proliferate. 900 MHz devices can be bought at corner stores. When the 900 MHz band has become saturated, with or without AVM, many manufacturers may direct new product efforts to the next available band, at 2400 MHz. Most of these products will not be 802.11-compliant.

It took more than four years after adoption of the new Part 15 Rules for 900 MHz products to start emerging, and four more for broad market development. Now that the onslaught has commenced, the band is close to overflow. Will the 2400 MHz band develop similarly?

[14] Note that this chart differs from Fig. 1, in that it shows the cumulative number of outstanding licenses, not new licenses granted in the time interval.

[15] See also Ron Schneiderman, "RFID Tags Locate Growing Wireless Market," Microwaves and RF, February 24, 1994, pp. 31-36. The article describes both 900 and 2400 MHz RF ID technologies.

B) 2400 MHz. It's already a jungle out there.

Now this is the law of the jungle—as old and as true as the sky;
And the Wolf that shall keep it may prosper,
but the Wolf that shall break it must die.
R. Kipling, The Second Jungle Book (1885)

Most attention of 802.11 is focused now on the 2400 MHz ISM band, even though most WLAN equipment now being marketed operates in the 900 MHz band. That the 2400 MHz band is already encumbered by microwave ovens has long been understood and accepted. Characterization of their impact has been competently addressed in 802.11. Less apparent are other devices that use the band, but anyone who drives with a radar detector knows how pervasive such devices are.

Just as the specter of an AVM takeover of the 900 MHz band drew forth comments from intended users, as reported above, a similar threat to communications in the 2400 MHz band flushed out true "ISM" (Part 18) users of that band.

> Microwave powered lighting is a nascent technology that, because it offers high efficiencies, is being promoted by the Department of Energy and private concerns. Most installations to date have been in industrial environments, such as parking lots, but office and residential products will be released this year.
>
> Fusion Systems described their lamps to the Commission: "A typical system employing two rows of eight, 3000 Watt, lamp modules has a tunnel opening at either end . . . (and) [o]ur best estimate is that a typical system may measure an average of 5 mW/cm^2 . . . that computes to 33 Watts of total microwave power radiated out of the system into free space." Fusion's products "currently occupy the entire 100 MHz spectrum" of 2400-2500 MHz.[16]
>
> Other testimony cites "thousands of microwave powered ultraviolet lamps for industry, with power levels ranging from 1500 to 6000 Watts per lamp module, " and installations involving "a 16 module 48,000 Watt microwave powered lamp system."
>
> In addition to Fusion Systems, both Philips and GE are reported to offer 2400 MHz lighting systems. The Smithsonian Air and Space Museum in Washington is reportedly scheduled for installation of microwave lighting this year, and a major federal office building in Washington may also be retrofit. Lamp modules in the 25 watt (in terms of light) range are reportedly ready for introduction, which could place them in office locales where wireless LANs could be functioning (or just on the other side of a partition).
>
> High power lighting devices which use magnetrons show similar µwave characteristics to ovens; that is, they nominally are centered in the ISM band and occupy tens of MHz instantaneously and more during longer periods, and as they age, they tend to drift lower in frequency and emit more signals into their surroundings. Makers of microwave lighting and heating devices are aware that it may become necessary to narrow their bandwidth; this can be accomplished only at a substantial cost.

[16] See Comments and Reply Comments of Fusion Systems, Inc., of FCC Docket 89-554 , which addressed satellite allocation issues in preparation for WARC '92.

The Wireless Cable Association advised the FCC in 1991 that their members required the 2400 MHz band to bypass or supplant cable for more than 80 communities, with many hundreds of thousands of subscribers.

The Association of Home Appliance Manufacturers told the FCC that microwave ovens are found in 83% of homes, representing some 81 million units that do not include office use. They also indicated that about 50% of these have been put into service in the last four years (suggesting that many older, more leaky units still remain).

The International Microwave Power Institute deduced that, based on market penetration, over 233 BILLION (their emphasis) heating operations will be performed by microwave ovens in the next 12 months in the U.S. They report measurements showing that a given oven can have a radiation field variation at, e.g., 2410 MHz, of "as much as 40 dB during any few minutes of oven operation." They conclude that "to commit great sums of money on the basis of presumed tolerance of microwave-oven noise with its tremendous statistical variation could be foolhardy, indeed."[17]

These comments have a surreal quality to them in the context of a communications industry. Rarely do manufacturers claim to be vicious, predatory users of the spectrum. However, as the intended primary beneficiary of the true "ISM" provisions in the rules, these occupants have a priority over unlicensed wireless LANs. Like cohabiting with that fabled 800-pound gorilla, we have to adapt to whatever it wants if we are to survive.

This list only touches the surface and has addressed only some of the many non-listening band users; that is, those who cannot be expected to defer politely, "listen before cook," or docilely follow 802.11's rules.

Obviously, there is a missing element in this discussion: the plans of the attendees and participants in this and other 802.11 meetings. In the AVM proceeding, the EIA offered a perspective that may be taken seriously:

> "EIA/CEG firmly believes that the product available to date represents a small fraction of the innovative devices that will soon be available for use. . . . Manufacturers are naturally reluctant to give their competitors advance knowledge of their product plans, but design and development work is apparently far along for many new products that use these frequencies. . . . Scores of manufacturers, thousands of retailers, and millions of consumers have made investments in Part 15 technologies and products."[18]

If the pattern of equipment approvals shown in Fig. 1 follows true to form, the four-year offset for the next wave of product introductions is upon us, and products from 802.11 members will start popping out rapidly. We would be well advised to heed history's indicators, and prepare our products to survive a turbulent, untamed environment where we are low on the food chain.

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[17] The two technical reports filed by the IMPI in FCC Docket 89-554 are quite comprehensive. This writer will provide copies on request.

[18] Comments of the Consumer Electronics Group of the Electronic Industries Association, filed on FCC Docket 93-61, June 29, 1993.

V. SURVIVAL IS THE ISSUE. THE KEY WORD IS RELIABILITY.

In this interference-prone context, Apple made its architectural decisions on its frequency hopping system. There was no expectation that the FCC would offer regulatory palliation of any interference problems. Apple decided at the outset that a responsible product program should use every technical means to survive and even thrive in a domain replete with interference, and especially with interference generators that would neither understand nor care that our products exist.

The largest single temptation was to respond as those whose only experience says "we haven't experienced any interference." Product design would be simplified. Throughput, in marketing terms, could be somewhat higher in a totally cleared band if no measures are taken to assure or enhance that throughput in a real life condition. Apple runs the risk of losing "bragging rights" on performance--for a brief period of history, or until a trade journal runs benchmark tests in at least an approximation of the real world.

However, the world has been tantalized with wireless, and formed expectations for high reliability that must be met if the whole market isn't to be tainted by fragile connectivity that works part-time. *Consummation* of communications appears more essential than the rate at which it is accomplished.

Apple ultimately chose a dual course:

1. To imbed carefully rationalized error-correcting-cum-channel-using schemes, taking into account the expected nature of interference from all sources. We believe that gaining extremely high probability of "getting through" far overshadows any short-burst success scheme that is intermittently unsuccessful. This approach translated, among other things, to dispersing any single meta-packet over as much of the available band as possible, loaded with enough coding that individual channel outages don't produce failure of the system. This scheme has been previously described to 802.11. As Apple stated to the FCC three years ago,

> "The presence of uncontrollable interference dominates the effort to achieve adequate throughput rates of data transmission on the ISM bands. . . . In planning spectrum usage, it is necessary to strike a judicious balance between providing a high quality transmission environment and burdening the channel with the additional overhead required to assure robust data transfer."[19]

2. Apple initiated efforts to obtain spectrum that would permit only a limited variety of defined forms of interference, from equipment intended for similar communications purposes. At this writing, it is not clear that the allocation thus achieved will come forth from its regulatory "spectrum purgatory."[20] When that allocation becomes available, we expect the industry to wheel en masse, like the wildebeests traversing the Serengeti, and head for a spectrum environment that will not require extraordinary technical measures to convey data confidently.

---

[19] Apple Petition, Data-PCS, RM 7618, January 28, 1991.

[20] Of course, the writer is referring to Apple's Data-PCS petition that culminated in the FCC's allocation of a band encumbered by hundreds of fixed-point microwave stations, that must be removed, at the cost of tens of $ Millions, before the band can be used for nomadic data communications devices. The task is just getting under way.

In the meantime, Apple believes that its frequency hopping approach to the medium represents the most hopeful way to achieve the data integrity called for in the PAR of 802.11. It's a matter of adapting to the environment and thriving in spite of it, until we can improve it.

But then,

"What experience and history teach is this: that people and governments never have learned anything from history, or acted on principles deduced from it.
Hegel, 1832.

Addendum

IMPACT OF THE BUDGET RECONCILIATION ACT OF 1993.

On February 10, 1994, the National Telecommunications and Information Administration (NTIA) identified to the FCC and Congress a total of 50 MHz that could be transferred virtually immediately from the primary domain of the NTIA, which administers all federal government spectrum, to public use administered by the FCC. This was in response to mandates in the budget bill, which were vestiges of the Emerging Telecommunications Act(s) of 1989-90-91-92-93, which heretofore had never survived the congressional gauntlet. At a later time, 150 more MHz will be similarly identified, for transfer between now and the year 2008.

Included in the first 50 MHz was 15 MHz, 2402 to 2417 MHz, that lies squarely amidst the so-called "ISM" band addressed in this paper.

The most obvious ramification of this transfer is that the Federal Government no longer intends to assert its right to use the band for high-powered radars. This should gladden the souls of product designers intending to use this band.

The other side of this picture is that the FCC now will have total dominion over the band, and can inject licensed services into it, if this seems appropriate. Considering the furor over AVM systems, discussed above, and the turmoil about PCS, "private PCS" as proposed by public agencies, direct broadcast satellites and other "emerging technologies," it would be possible that the band, bad as it is, could get worse, and be put in the hands of applications with primary status (such as AVM). In that case, one might anticipate that these licensed primary users might find it necessary to force interfering unlicensed, secondary services to cease operation.

Instead of assuming that the change in management of part of the 2400 MHz band will improve our lot, IEEE 802.11 members should be vigilant and head off any measure that would impair the 2400 MHz band. The most effective weapon will be the development of products for the band that demonstrate substantial social utility and market success.

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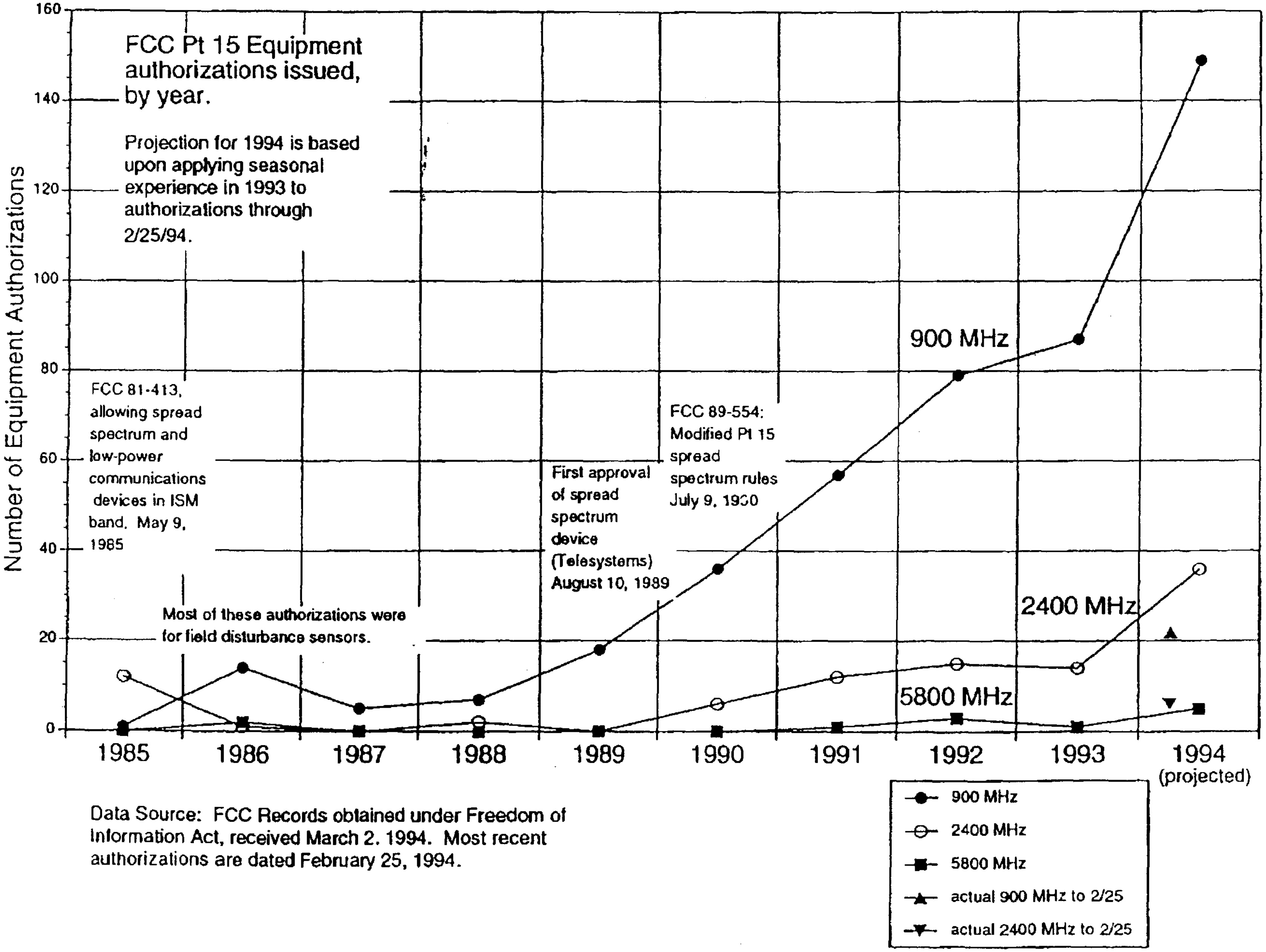
FCC Pt 15 Equipment authorizations issued, by year.
Projection for 1994 is based upon applying seasonal experience in 1993 to authorizations through 2/25/94.
Number of Equipment Authorizations
0
20
40
60
80
100
120
140
160
FCC 81-413, allowing spread spectrum and low-power communications devices in ISM band. May 9, 1985
Most of these authorizations were for field disturbance sensors.
First approval of spread spectrum device (Telesystems) August 10, 1989
FCC 89-554: Modified Pt 15 spread spectrum rules July 9, 1990
900 MHz
2400 MHz
5800 MHz
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994 (projected)
900 MHz
2400 MHz
5800 MHz
actual 900 MHz to 2/25
actual 2400 MHz to 2/25
Data Source: FCC Records obtained under Freedom of Information Act, received March 2. 1994. Most recent authorizations are dated February 25, 1994.